The North Sea Mackerel Egg Survey: Changing from the Annual to Daily Egg Production Method.

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Introduction

The working group on mackerel and horse mackerel egg surveys (WGMEGS) coordinates the Mackerel and Horse Mackerel Egg Survey in the Northeast Atlantic and the Mackerel Egg Survey in the North Sea with the purpose of estimating the spawning stock biomass of the different NEA mackerel spawning components since 1977 (Lockwood et al. 1981). These surveys are carried out triennially, although the North Sea survey is normally completed one year after the western and southern area surveys. The survey for the western area mackerel was initiated in 1977. The southern area was later added in 1992 (ICES, 1993).

Egg production survey methods

Egg production surveys provide a method of estimating SSB, independent of any data on commercial catches, to be integrated in or used to inform the stock assessment process.

The underlying concept for egg production methods is very simple; if we know how many eggs have been spawned over a period of time (e.g. daily or annually) in the spawning area (egg production), and we know how many eggs an average individual mature female can produce over the same period (fecundity), then we can estimate the size of the spawning population (Bernal et al., 2012).

There are two primary methods (Gunderson 1993; Hunter and Lo 1993), namely the annual egg production method (AEPM) and the daily egg production method (DEPM). The first method is designed for species with a determinate fecundity, i.e. those in which all the eggs to be spawned during the year are present and identifiable in the ovary immediately prior to spawning (Potential fecundity). With the AEPM, estimated egg production is integrated over the whole annual spawning season, using data from a series of surveys, and how many eggs are produced on average per unit mass of spawning female in the year. Whereas the application of AEPM is suitable only for determinate annual spawners, the DEPM can in principle be applied to indeterminate and determinate spawners that release pelagic eggs in a series of batches and for which the daily spawning fraction and batch fecundity can be estimated with sufficient accuracy (Kraus et al., 2012).

The DEPM can be used for species with an indeterminate fecundity, in which the potential annual fecundity is not fixed before the onset of spawning (Stratoudakis et al., 2006) and previtellogenic oocytes are recruited over the spawning season. The DEPM requires a single ichthyoplankton survey covering the entire spawning area during a brief period of the

spawning season to estimate the mean daily egg production and to have representative samples of spawning adults during the survey period in order to estimate the mean daily fecundity (batch fecundity, spawning fraction and sex ratio) per unit mass of adults, at or near the annual peak of spawning (Parker, 1980, Stratoudakis et al., 2006). Accordingly the DEPM provides a snapshot rather than an integrated view of the spawning season (Stratoudakis et al., 2006).

The main difference of the DEPM in relation to the AEPM method resides on the appropriate measure of fecundity, which in the case of indeterminate spawners has to be based on the number of oocytes released per fish in each spawning event (batch fecundity) and the proportion of females reproducing daily (spawning fraction) (Stratoudakis et al., 2006).

Mackerel egg survey

Since 1977 the AEPM has been used for estimation of NEA mackerel SSB (Lockwood et al. 1981; Lockwood 1988) under the assumption that mackerel has a determinate fecundity. However, Greer Walker et al. (1994) had shown that the assumption of mackerel having a determinate fecundity was not conclusive and concluded 'that for all practical purposes the mackerel should be considered as having a determinate fecundity". Priede and Watson (1993; 1997) compared the use of the Daily Egg Production Method (DEPM) and Annual Egg Production Method (AEPM) for the estimation of spawning-stock biomass (SSB) in mackerel during the 1989 and 1992 egg surveys. These estimations showed inconsistent results.

In 2012 WGMEGS coordinated the Workshop on Survey Design and Mackerel and Horse Mackerel Spawning Strategy (WKMSPA) (ICES, 2012b) to discuss spawning strategies of mackerel and horse mackerel and to make recommendations on the survey design. The reason for organising this workshop was that observations from egg surveys in 2007 and 2010 seemed to indicate that mackerel (and horse mackerel) have an indeterminate fecundity type. This workshop recommended that extra adult samples should be collected on surveys to investigate the estimation of DEPM adult parameters, and to attempt a contrast between AEPM and DEPM results and review fecundity samples collected in previous surveys for DEPM adult parameters

The North Sea Mackerel Egg Survey (NS-MEGS) is designed to estimate the spawning stock biomass (SSB) of the North Sea spawning component of Northeast-Atlantic mackerel. Up to 2017 this was done utilizing the annual egg production method (AEPM). This method estimates and combines total annual egg production (TAEP), realized fecundity per gram female, and sex (male to female) ratio to calculate SSB. TAEP of mackerel spawning in the North Sea is based on counts of freshly spawned (stage 1) eggs from plankton catches, which ideally cover the entire spawning area and season. Temporal coverage is achieved through several passes of the entire spawning area during the spawning season. Realized fecundity is estimated based on histological examinations of pre-spawning (for potential fecundity) and spawning ovaries (for atresia estimation) from caught mackerel. For details on methods see the respective WGMEGS survey manuals (ICES 2019 a, b).

The NS-MEGS was first carried out in 1980, and continued on an annual basis until 1984, before being conducted biennially until 1990. No NS-MEGS surveys were carried out between 1990 and 1996. The survey was restarted in 1996 and has been carried out

triennially since, similar to the Northeast-Atlantic MEGS (NEA-MEGS), however it always takes place one year after the western and southern surveys. In the early years of the survey, prior to 1990, more than 90 ship days were allocated to the survey, however since the re-instatement of the survey in 1996 this effort was much reduced to approximately 30 days per year. The number of participating nations also declined, from at least three in the beginning to two after 1996 (at first Norway and Denmark, later Norway and The Netherlands). After the 2011 survey, and coinciding with the 2014 benchmark for mackerel stock assessment, Norway decided to withdraw from the NS-MEGS, leaving The Netherlands as the only participating nation (ICES 2014). In an effort to continue providing good quality data the Netherlands increased its survey time from 15 to 20 days after the withdrawal of Norway.

Spatial and temporal coverage had already been impacted when the survey was re-initiated in 1996, due to the reduction in available survey effort, and this became even more serious with the withdrawal of the Norwegian participation. Due to technical difficulties with the Dutch survey vessel the 2014 North Sea survey had to be postponed until 2015. In 2020 Covid-19 measures again prevented the survey being carried out, so it was postponed until 2021.

Prior to 2011 Norway was responsible for calculating TAEP and SSB for North Sea mackerel. After the withdrawal of Norway, discrepancies in the estimation of the TAEP were found compared to the current method described in the WGMEGS manual. This discrepancy rendered the 2015 and 2017 estimates inconsistent with the earlier estimations in the NS-MEGS time series. This became particularly noticeable for the 2015 NS-MEGS (Figure 1 and Table 1). The 2015 egg production curve is almost entirely below the curves of the 2008 and 2011 surveys, but still delivers a higher TAEP estimate. In addition, the 2017 egg production curve does not really suggest a higher TAEP than the one of 2005. However, the 2017 TAEP exceeds 2005 by almost a third.

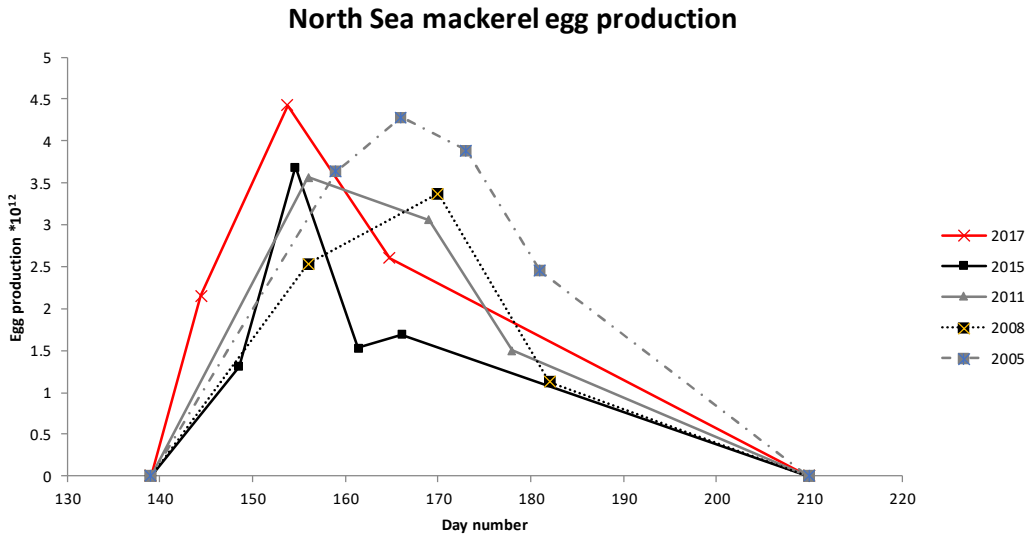

Figure 1: Annual egg production curves for North Sea mackerel (prior to 2015 the Lockwood egg development equation was used, since 2015 the Mendiola equation was used).

Table 1: Egg production estimates from egg surveys 2005 – 2017 in the North Sea and corresponding SSB based on a standard fecundity of 1401 eggs/g/female.

Year	Egg prod *10^{12}	SSB *10^{3} tons
2005	155	223
2008	108	154
2011	116	165
2015	119	170
2017	201	287

These inconsistencies in the time series have remained unexplained. Currently it is not known how TAEP was calculated by Norway before they withdrew from the survey, the methodology used was never described in the WGMEGS manual. However, two reasons may explain the discrepancies:

1. As documented in the survey manual (ICES 2019b) WGMEGS had decided in 2013 to replace the Lockwood development equation with one developed by Mendiola. As a result, in 2015, the Netherlands used the Mendiola equation for the first time in the North Sea convert egg abundance into daily production. Using the Mendiola equation leads to higher egg production compared to the Lockwood equation. The time series for the western and southern surveys has been recalculated using the Mendiola equation, this work still needs to be carried out for the North Sea.

2. For the recent egg surveys, and following the latest versions of the MEGS manual, TAEP was calculated as the area under the histogram, while according to the methodology for surveys prior to 2015, the area under the curve was utilized (ICES 1997, 2000, 2003, 2006, 2009, 2012), which may also contribute to a lower estimate in those years.

The North Sea time series data still awaits thorough quality assurance checks and re-analysis with respect to the above-mentioned inconsistencies.

Another problem for the NS-MEGS is that since 1982 it has been impossible to collect pre-spawning mackerel, which are necessary to estimate the potential fecundity. For North Sea SSB estimation MEGS have used the realized fecundity value from the 1982 estimate (Iversen and Adoff, 1983). Both in 1998 and 2001 the realized fecundity in the western area was re-estimated but considered to be rather low (ICES 2002) and WGMEGS decided to reject these estimations (ICES 2000, 2003).

In 2018 WGMEGS, (ICES 2018), after assessing the quality of the 2017 NS-MEGS results, decided that future North Sea surveys, starting in 2020, would use a DEPM sampling scheme rather than AEPM. Even with the inclusion of Denmark the limited ship time available would

not be sufficient to provide adequate coverage of mackerel spawning in the North Sea either temporally or spatially using the AEPM approach (ICES 2018). The DEPM only requires one full coverage of the spawning area over a shorter time period, and preferably during peak spawning. Full coverage of the spawning area can, due to its spatial confinement, be much easier achieved in the North Sea than in the open Northeast-Atlantic. Sampling during peak spawning is preferred because of the increased chances of catching spawning mackerel for batch fecundity and spawning fraction estimations. However, this method also requires a large number of adult samples to be collected and analysed to estimate reliable batch fecundity and spawning fraction estimation. However because only one coverage of the spawning area is necessary for daily egg production, it was predicted that sufficient ship time would be available to collect the higher number of adult samples necessary. The application of DEPM would enable WGMEGS to deliver a more robust estimate of the SSB of the North Sea mackerel stock component compared to any of the previous years since 1996.

Because of the Covid-19 pandemic, the 2020 NS-MEGS had to be postponed to 2021, when it was carried out successfully in May-June. For the first time, the entire North Sea spawning area could be covered and enough adult female mackerel were caught for the necessary fecundity and spawning fraction estimations. It is, therefore, anticipated that for the first time a robust estimate of the SSB of the North Sea spawning component of mackerel will become available.

References

Bernal, M., Somarakis, S., Witthames, P. R., van Damme, C. J. G., Uriarte, A., Lo, N. C. H., and Dickey-Collas, M. 2012. Egg production methods in marine fisheries: an introduction. Fisheries Research, 117–118: 1–5.

Gunderson, D.R. (1993) Surveys of Fisheries Resources. Wiley, New York. 248 pp.

Greer Walker, M., P. R. Witthames & I. Bautista de los Santos (1994) Is the fecundity of the Atlantic mackerel (Scomber scombrus: Scombridae) determinate?, Sarsia, 79:1, 13-26.

Hunter, J.R. and Lo, N.C.H. (1993) Ichthyoplankton methods for estimating fish biomass: introduction and terminology. Bulletin of Marine Science 53, 723–727.

ICES. 1993. Report of the Mackerel / Horse mackerel Egg Production Workshop. ICES CM 1993/H:4. 142 pp.

ICES 1997. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys. Lisbon, Portugal, 3 – 7 February 1997. ICES CM 1997/H:4. 48 pp.

ICES 2000. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys. Santander, Spain, 18 – 21 January 2000. ICES CM 2000/G:01. 54 pp.

ICES 2002. Report of the Working Group on Mackerel and Horse Mackerel Surveys. ICES CM 2002/G:06.

ICES 2003. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys. 1 – 4 April 2003, Lisbon, Portugal. ICES CM 2003/G:7 Ref. D. 57 pp.

ICES. 2006. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 27–31 March 2006, Vigo, Spain. ICES CM 2006/LRC:09, Ref. RMC. 75 pp.

ICES. 2009. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 20–24 April 2009, Hamburg, Germany. ICES CM 2009/LRC:09. 107 pp.

ICES. 2012. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 18-21 April 2012, Galway, Ireland. ICES CM 2012/SSGESST:04. 135 pp.

ICES 2012b. Report of the Workshop on Survey Design and Mackerel and Horse Mackerel Spawning Strategy (WKMSPA), 16-17 April 2012, Galway, Ireland. ICES CM 2012/SSGESST:05. 28 pp.

ICES. 2014. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 7-11 April 2014, Reykjavik, Iceland. ICES CM 2014/SSGESST:14. 110 pp.

ICES. 2018. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 9-13 April 2018, Marine Institute, Dublin, Ireland. ICES CM 2018/EOSG:17 70 pp.

ICES 2019a. Manual for the AEPM and DEPM estimation of fecundity in mackerel and horse mackerel. Series of ICES Survey Protocols SISP 5. 89 pp. http://doi.org/10.17895/ices.pub.5139

ICES 2019b. Manual for mackerel and horse mackerel egg surveys, sampling at sea. Series of ICES Survey Protocols SISP 6. 82 pp. http://doi.org/10.17895/ices.pub.5140

Iversen, S.A. and Adoff, G.R. 1983. Fecundity observations on mackerel from the Norwegian coast. ICES C.M.1983, H:45, 6pp.

Kraus et al., 2012 G. Kraus, H.-H. Hinrichsen, R. Voss, E. Teschner, J. Tomkiewicz, F.W. Köster. Robustness of egg production methods as a fishery independent alternative to assess the Eastern Baltic cod stock (*Gadus morhua callarias* L.). Fisheries Research, 117–118 (2012), pp. 75-85

Lockwood, S. J., Nichols, J. H., and Coombs, S. H. 1977. The development rates of mackerel (*Scomber scombrus* L.) eggs over a range of temperature. ICES CM 1977/J:13, 8pp.

Lockwood, S.J., Nichols, J.H., Dawson, W.A., 1981. The estimation of a mackerel (*Scomber scomber L.*) spawning stock size by plankton survey. J. Plankton Res. 3, 217−233.

Lockwood, S.J. – 1988. The mackerel. Its biology, assessment and the management of a fishery. Fishing Book News Ltd. Farn-ham, Surrey England. 181 pp.

Parker, K. (1980) A direct method for estimating northern anchovy, *Engraulis mordax*, spawning biomass. Fishery Bulletin 78, 541–544.

Priede, I.G., Watson, J.J., 1993. An evaluation of the daily egg production method for estimating biomass of Atlantic mackerel (*Scomber scombrus*). Bull. Mar. Sci. 53, 891−911.

Priede, I.G., Watson, J.J., 1997. Some observations on spawning biology of Atlantic mackerel (*Scomber scombrus*) and the application of egg production methods for estimation of spawning stock biomass. Ozeanografika, 2, 149-163.

Stratoudakis, Y., Bernal, M., Ganias, K., and Uriarte, A. 2006. The daily egg production method: recent advances, current applications and future challenges. Fish and Fisheries, 7: 35–57.